University of California, Berkeley
Physics H7C Fall 1999 (*Strovink*)

PROBLEM SET 8

1.
(a.)
Consider a distant star with the same luminosity and surface temperature as the sun. A person (who is as "efficient" as one of Rutherford's graduate students) can see the star if 250 visible photons per second pass through her pupil, which has a radius of 2 mm when nearly fully dilated. What is the maximum distance at which the star is visible to the naked eye?
(b.)
How many cosmic photons per second per square cm were incident on the Nobel-Prizewinning microwave antenna of Penzias and Wilson?

2.
(a.)
The maximum energy of photoelectrons from aluminum is 2.3 eV for incident radiation of 0.2 μm and 0.9 eV for radiation of 0.313 μm. Use these data to calculate Planck's constant and the work function of aluminum.
(b.)
An aluminum photocathode receives incident radiation of 0.313 μm. When the intensity of this radiation is 1 mW, a current of 1 μA is observed in a circuit that detects the photoelectrons that are liberated. Estimate the quantum efficiency of the photocathode.

3.
Rohlf 3.20.

4.
(a.)
The power radiated by an accelerated charge e is given in classical physics by the formula

$$P = \frac{1}{4\pi\epsilon_0}\frac{2e^2}{3c^3}a^2 \quad \text{(SI units)},$$

where a is the acceleration. Using this formula, calculate the power radiated by an electron in a Bohr orbit characterized by the quantum number n. No numbers are required. (According to the correspondence principle, when n is very large this should agree with a proper quantum mechanical calculation.)
(b.)
The decay rate for an electron in an orbit may be defined to be the power radiated, P, divided by the energy emitted in the decay. (The decay rate is the inverse of the lifetime). Use the Bohr theory expression for the energy radiated, and the expression for P from part (a.) to calculate the "correspondence" value of the decay rate when the electron makes a transition from orbit n to orbit $n-1$. What is the value of this decay rate when $n = 2$? (This will not agree exactly with the true quantum theory, since the correspondence principle will not hold when n is not $\gg 1$.) What is the decay rate when the transition is from an orbit n to an orbit $n - m$?
(c.)
Use the value of the "lifetime" of an electron in an $n = 2$ Bohr orbit, calculated in part (b.), to estimate the uncertainty in the energy of the $n = 2$ energy level. How does it compare with the energy of that level?

5.
Rohlf 3.42.
Do the first part of the problem. Then answer the final question posed in this problem for two extreme cases:
(a.)
The muon capture probability is of the same order of magnitude as the decay probability.
(b.)
The muon capture probability is many orders of magnitude smaller than the decay probability.

6.
There exists a fundamental constant of nature $\mathcal{O}$ whose value is 25,813 ohms. Calculate the ratio between the numerical value of $\mathcal{O}$ and the numerical value of Z_0, the characteristic impedance of free space. Using any hint that you can obtain from this ratio, determine the *algebraic* value

of $\mathcal{O}$, expressed in terms of other fundamental constants.

7.
Rohlf 3.56.

8.
Rohlf 4.54.